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13. ABSTRACT *(Maximum 200 words)*

Significant Accomplishments

The PI and his students have developed novel algorithms for boundary computation, model simplification, fast display and interference detection. These include use of exact arithmetic for robust and accurate boundary computation, development of an interactive solid modeler using parallel algorithms and implementations, simplification with guaranteed error bounds for large polygonal models, occlusion culling, interactive display of large spline models and efficient collision detection between general polygonal models.

The resulting algorithms and systems have been applied to a number of applications and the technology has been transferred to a number of research and DOD labs as well as commercial vendors.

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PROJECT TITLE: Model Construction and Interactive Walkthrough of Large CAD Models

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## 1. Technical Objectives and Motivation

We are addressing some fundamental research issues in modeling, display and simulation for computer-aided design and virtual environments. Our emphasis is to develop better algorithms and software systems and to demonstrate their applications. The set of problems include:

A. Robust and interactive algorithms for modeling physical objects using boolean operations.
B. Hierarchical and multiresolution representations of models for fast display.
C. Develop a robust system to compute boundary representation of solids defined using boolean combination of sculptured models and integrate it with the BRL-CAD solid modeling system.
D. Interactive display of large scale polygonal, sculptured and solid models on current graphics systems.

## 2. Approach

We are utilizing number of techniques from algebraic geometry, approximation theory, computational geometry, numerical analysis, computer-aided geometric design and computer graphics to investigate the underlying mathematical concepts and to develop more efficient and robust geometric algorithms. This includes algorithms and systems for computing boundary representations of constructive solid geometry models composed of spline primitives and their boolean combinations. In particular, we propose to compute accurate spline representations of the intersection curve with guaranteed error bounds and make use of a number of algorithms from computational geometry and discrete mathematics to represent the topologies of the given solids. The resulting system is being integrated with BRL-CAD and being applied to computing an accurate boundary representation of a Bradley fighting vehicle. We are also developing improved algorithms for polygon and surface triangulation, simplification, visibility and hierarchical representations for developing interactive systems for displaying large datasets. Eventually, we will interface these systems with the immersive hardware and apply them for interactive walkthrough of the fighting vehicle.

## 3. Significant Accomplishments

The PI and his students have developed novel algorithms for boundary computation, model simplification, fast display and interference detection. These include use of exact arithmetic for robust and accurate boundary computation, development of an interactive solid modeler using parallel algorithms and implementations, simplification with guaranteed error bounds for large polygonal models, occlusion culling, interactive display of large spline models and efficient collision detection between general polygonal models.

The resulting algorithms and systems have been applied to a number of applications and the technology has been transferred to a number of research and DOD labs as well as commercial vendors.

4. Cooperation with and Technology Transfer to Army Laboratories and Other Organizations

A: {\bf Army Research Labs, Aberdeen, MD:} The PI and his graduate students are integrating our solid modeler, BOOLE, with the BRL-CAD solid modeling system developed by researchers at Army Research Labs, Aberdeen. BRL-CAD is primarily used for {\em vulnerability analysis} at ARL and it has more than $1600$ users worldwide. BOOLE will be used for performing boolean operations on curved surfaces.

B: {\bf I-COLLIDE Collision Detection System:} More than $700 $ users all over the world have copied the source code of the I-COLLIDE collision detection system. Some of the prominent users are at Sandia National Labs, Lockheed Martin, Ford Motor Company, Division, Engineering Animation, Army Research Labs, Evans and Sutherland, etc. The system has also been licensed to Mechanical Dynamics Inc. and Division Inc.

C: {\bf White Sands Missile Range, NM:} The algorithms and systems for collision detection have been incorporated into a {\em missile distance display scenario}. The purpose of the scenario is to produce a visual display of the results of an engagement between a missile and a target. The main objective is to provide information in sufficient detail to permit missile system performance evaluation.

D: {\bf Lockheed-Martin, Electric Boat and Newport News Shipbuilding:} The PI and his students have been actively collaborating with researchers at these organizations and other universities for more than two years as part of ARPA's project on {\em Simulation-based Design}. In particular, the software technology for model generation, simplification and fast display is being used for interactive walkthrough of submarines and ship-models.

E: {\bf Air Force's Philip Laboratory, NM:} The solid modeling and fast rendering systems, developed at UNC, are used for model generation and fast display of satellite systems.

F: {\bf RAPID Interference Detection System:} More than $400 $ users all over the world have copied the source code of the RAPID interference detection system. Some of the prominent users are at Intel, Numerical Design Limited, Ford, Division etc.

5. Publications in Refereed Journals and Conference Proceedings


1. Scalable Algorithms for Interactive Visualization of Curved Surfaces S. Kumar, C. Chang and D. Manocha, Proc. of SuperComputing'96. Received Best Student Paper Award.

2. Interactive Display of Large-Scaled NURBS models, S. Kumar, D. Manocha and A. Lastra, IEEE Transactions on Visualization and Computer Graphics , Dec. 1996.

3. Efficient B-rep Generation of Low Degree Sculptured Solids Using Exact Artihmetic (35 pages) J. Keyser, S. Krishnan, D. Manocha, Technical Report TR96-040, Department of Computer Science, University of N. Carolina, Chapel Hill.

4. High Speed and High Fidelity Visualization of Complex CSG Models, S. Kumar, S. Krishnan, D. Manocha and A. Narkhede BCS International Conference on Visualization and Modeling, Leeds, UK, 1995.

5. An Efficient Surface Intersection Algorithm based on Lower Dimensional Formulation, S. Krishnan and D. Manocha, to appear in ACM Trans. on Computer Graphics, Jan 1997.

6. BOOLE: A System to Compute Boolean Combinations of Sculptured Solids, S. Krishnan and D. Manocha, Proc. of CSG'96, Winchester, England.

7. Algebraic Loop Detection and Evaluation Algorithms for Curve and Surface Interrogations, S. Krishnan and D. Manocha, Proc. of Graphics Interface'96, Toronto, 1996.

8. Hierarchical Backface Computation (19 pages) S. Kumar, D. Manocha, W. Garrett and M. Lin. Proc. of 7th Eurographics Workshop on Rendering, 1996.

9. Hierarchical Visibility Culling for Spline Models, S. Kumar and D. Manocha. Proc. of Graphics Interface, Toronto, Canada, 1996.

10. Simplification Envelopes, J. Cohen, A. Varshney, D. Manocha, G. Turk et al., Proc. of Siggraph'96.

11. OBB-Tree: A Hierarchical Structure for Rapid Interference Detection, S. Gottschalk, M. Lin and D. Manocha, Proc. of ACM Siggraph'96.

12. Efficient and Accurate Interference Detection for Polynomial Deformation, M. Hughes, C. DiMattia, M. Lin, D. Manocha, Proceedings of the Computer Animation '96 Conference.

13. S. Kumar and S. Krishnas and D. Manocha. "Interactive display of large solid models for walkthroughs", IEEE Computer Graphics and Applications, pp. 9-11, March 1996.

14. S. Kumar and D. Manocha. "Dynamic mesh generation for parametric iso-surfaces". Proceedings of 5th International Conference on Numerical Grid Generation in Computational Fluid Dynamics and Related Fields", 1996.

15. S. Kumar and D. Manocha. "The power of coherence: fast tessellation of surfaces". Proceedings of ACM Computational Geometry Conference, 1996.

6. Awards and Honors (if any, omit this section if none)

A: The P.I. was awarded NSF Career Award.

C: P.I's student, Subodh Kumar, received the best student paper award at SuperComputing'96 conference, for the paper titled: "Scalable Algorithms for Interactive Visualization of Curved Surfaces, S. Kumar, C. Chang and D. Manocha. He is currently as Assistant Professor of Computer Science at Johns Hopkins University.

7. Papers or reports in non-refereed publications

1. S. Krishnan, S. Kumar and D. Manocha. "Boundary Computation of CSG Models with NURBS Primitives", Proc. of IFIP Workshop on Computer Aided Design, May 1996.

2. M. Lin, D. Manocha, S. Gottschalk, J. Cohen, "Collision Detection: Algorithms and Applications", Proc. of IInd Workshop on Algorithmic Robotics, Toulouse, France, 1996.

8. Books or book chapters published

"Applied Computational Geometry: Towards Geometric Engineering", editors Ming C. Lin and Dinesh Manocha, Springer-Verlag, 1996.

9. Patent/Inventions filed or granted

10. Number of graduate and undergraduate students supported by gender and by minority group

S. Gottschalk (Ph.D student), male

M. Gopi (M.S. student), male

S. Krishnan (Ph.D. student), male

S. Kumar (Ph.D. student), male

J. Keyser (M.S. student), male

11. Number of MS and Ph.D. degrees awarded to students working through the gran t
and their current employment status and employers

M. K. Ponamgi: M.S. December 1995.
Current employer: Virtus Inc, RTP, NC.

S. Kumar: Ph.D. December 1996
Current employer: Johns Hopkins University, Baltimore.

12. Nonexpendable instrumentation purchased; value thereof